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SUPPLEMENTARY TESTS OF GYPSUM AS FIRE PROTECTION FOR BUILDING COLUMNS

The tests reported in this letter circular supplement the series of fire tests of building columns conducted in cooperation with the Factory Mutual Laboratories and the Underwriters' Laboratories, the results of which were reported in Bureau of Standards Technologic Paper No. 184.

It was observed in the 1917-19 tests that the shrinkage of the outer portions of the gypsum blocks under fire exposure opened up the horizontal joints, loosening the mortar from the blocks, until the metal ties in the joints were no longer effective. As the fire progressed, the blocks tipped outward and fell from the column long before the fire resistive value of the material had been developed.

The immediate object of the supplemental tests carried out in 1930-31 on six steel columns fireproofed with gypsum was to determine by comparison the effectiveness of anchors and of plaster coatings in holding the blocks in place. Gypsum concrete was also included, in order to determine the difference in protection afforded by precast units and monolithic poured covering.

The columns were all of 6-inch H-section fabricated from plates and angles. The protective coverings consisted of poured-in-place gypsum concrete or of solid or hollow gypsum block with metal anchors. Four of the columns were plastered as described later.

Column No. 1 was wrapped with 4 by 4 inch mesh of 14 gage welded wire fabric before the forms were set to receive the 2-inch thick wood-fibered gypsum concrete covering, which was plastered after being seasoned. The precast coverings of the other columns were made by sawing gypsum partition block to 15-inch lengths and ripping to width for the covering desired. As the blocks were set cramps made of 7/8 or 1 inch wide by No. 12 gage band iron were set to span between holes in adjacent blocks at each corner except for Column No. 3 which had strips of galvanized wire lath of No. 19 gage wire having 2 meshes per inch placed in the horizontal joints. This column also had its reentrant parts filled solidly. One and a quarter inch holes, 1 inch deep were drilled in the top ends of the solid blocks for insertion of the cramps.

All the gypsum block protections were set in mortar composed of 1 part of gypsum cement to 3 parts of sand by weight. In general the joints were 3/8 inch thick. The plaster was likewise of a 1 to 3 mix. It was applied 1/2 inch thick after the

mortar joints were dry in the ordinary "double-up" method and finished with lime putty and plaster of paris white coat when sufficiently dry. The tests were made in accordance with the American Society for Testing Materials Tentative Specifications for Fire Tests of Building Construction and Materials (C 19-26T) in a gas fired furnace equipped with a hydraulic jack for applying loads. Loads computed by the formula of the American Institute of Steel Construction were applied until the heated columns would no longer support them. Temperatures within the furnace and at four elevations in the steel column were measured by thermocouples.

The following tables give the principal details of test columns with gypsum protective coverings. It is divided into two sections, the first of which deals with the recent series of tests and the second with the series jointly conducted at the Underwriters' Laboratories and referred to previously. The columns in the earlier tests, Nos. 64 to 67A, were loaded about 10 per cent in excess of loads (lbs./in.^{2}) computed by the formula,

$$16000 - 70 \frac{l}{r}$$

The figures in parenthesis are allowable loads (lbs./in.^{2}) for these columns computed in accordance with the formula of the American Institute of Steel Construction,

$$\frac{18000}{1 + \frac{l^2}{18000\ r^2}}$$

and are inserted here for comparison.

Fire Resistance of Columns with Gypsum Protective Coverings
1930 - 1931

Steel columns made of four angles 3 in. by 2-1/2 in. by 1/2 in. and one plate 6 in. by 1/2 in. 13 ft. 1 in. long. Ratio of effective length (10 ft. 4 in.) to least radius of gyration (1.36 in.) 91.2

Col. No.	Steel Column	Protective Covering			Performance	
	Load	Details	Thickness over flange of Column	Net cross section of protection	Period of expansion	Fire endurance in test
	lbe/in.^{2}		In.	sq.in.	hr:min	hr:min.
1	12,700	2-in. monolithic wood fibered gypsum concrete with 4 by 4 in. 14 ga. wire mesh, 1/2 in. sanded gypsum plaster	2 1/2	117	6:30	6:54
2	12,700	3-in. hollow gypsum partition tile with four 1 in. by 12 ga. band iron cramps each course, 1/2 in. sanded gypsum plaster. No fill.	3 1/2	110	5:00	5:10
3	12,300	2-in. solid gypsum partition tile filled solidly inside with two 10 in. by 1 1/2 in. galvanized wire clothestrips 2 mesh per inch in each course, 1/2 in. sanded gypsum plaster.	2 3/4	140	5:30	5:47
4	12,300	3-in. hollow gypsum partition tile with four 7/8 inch by 12 ga. gand iron cramps in each course. No fill, no plaster	3	81	2:51 1/2	2:52
5	12,300	2-in. solid gypsum partition tile with four 7/8 in. by 12 ga. band iron cramps in each course. No fill, 1/2 in. sanded gypsum plaster.	2 1/2	94	4:05 1/2	4:21
6	12,300	2-in. solid gypsum partition tile with four 7/8 in. by 12. ga. band iron cramps in each course. No fill, no plaster.	2	71	2:31 1/2	2:33

Fire Resistance of Columns with Gypsum Protective Coverings
jointly conducted tests 1917-19

Col. No.	Steel column load[1]	Protective Covering			Performance	
		Details	Thickness over flange of column	Net cross section of protection	Period of expansion	Fire endurance in test
	lb./in.^{2}		in.	sq.in.	hr:min.	hr.min.
64[2]	11,750 (13,662)	4-in. solid gypsum block, 3/4 in. mortar between flange and block, 2 corrugated wall ties in horizontal joint over each vertical joint. Filled solidly inside with gypsum block and mortar. No plaster.	4 3/4	296	4:32	4:43 1/4
65[3]	12,670 (14,604)	2-in. solid gypsum block, corrugated wall ties in joints. Filled solidly with gypsum blocks and mortar. No plaster	3	126	2:20	2:21 1/2
66[4]	14,270 (15,000)	2-in. solid gypsum block, wire lath strips in horizontal joints. Filled solidly with 1:1:4 concrete of gypsum cement, sand and broken gypsum block. No plaster.	3 1/4	232	2:32	2:36
67[2]	11,750 (13,662)	4-in. solid gypsum block, wire lath strips in horizontal joints Filled solidly with 1:1:4 concrete of gypsum cement, sand and broken block. No plaster.	4 3/4	296	5:01	5:31 1/2
67A[2]	11,750 (13,662)	Same as No. 67.	4 3/4	296	5:45	6:24 1/2

(1) Allowable loads (lbs/in.^{2}) computed by American Institute of Steel Construction formula are given in parentheses.

(2) Steel column 8-in. H 34.5 lbs. Area 10.17 sq. in. $\frac{l}{r} = 75.6$

(3) Steel column Two 6-in. channels, 8 lbs.
Two 8 by 1/4 in. plates, area, 8.76 sq. in. $\frac{l}{r} = 64.7$

(4) Steel column Two 9-in. channels, 13 1/4 lb. $\frac{l}{r} = 44.0$

Discussion

A comparison of results of Test No. 3 with Tests Nos. 65 and 66 reported in Technologic Paper No. 184 of the Bureau of Standards would seem to indicate that a 1/2-inch plaster finish over the 2-inch block protection with solid fill gives over 3 hours additional fire protection. These columns were similar in point of protection except that the area of the unplastered protections was greater in the earlier tests, a difference that was in their favor. The greatly increased fire resistance developed by the column in the recent series can be attributed largely to the fact that with the plaster protection the shrinkage and cracking of the blocks was not as marked as in the previous tests and they remained in place until the temperature of the loaded column became so high as to cause failure. In the 1917-19 tests the shrinkage of the blocks destroyed the effectiveness of the bond afforded by the wire mesh or corrugated wall ties placed in the horizontal joints, the blocks tipped outward and fell off, exposing the flanges of the steel columns. The general temperature of the steel when the blocks began to fall off was near 100°C (212°F), following which it rose rapidly until failure under load occurred. For these columns under the applied loads the average column temperature in the region of failure would be near 600°C (1112°F), not far different from that observed in the supplemental tests.

A more direct measure of the value of the plaster finish can be had from a comparison of Test No. 2 with Test No. 4 and Test No. 5 with Test No. 6 in which the difference for each pair was only in the ommision of plaster. The difference in fire endurance of the first pair was 2 hours and 18 minutes and the second pair, 1 hour and 48 minutes. The effectiveness of plaster on the 3-inch hollow block is reflected by the comparison of the increase of net area, 34 per cent, with the 80 per cent increase in fire resistance. About the same relation holds in a comparison between solid block coverings. An increase of 32 1/2 per cent in area by plastering increased the fire resistance period by 70 1/2 per cent.

The effect of a positive bond between the units of each course of the unplastered solid block coverings may be judged by comparing Tests Nos. 4 and 6 with Nos. 66 and 65 respectively of the previous series. The column covering for Test No. 4 was made of 3-inch hollow gypsum blocks with band iron cramps in each corner of each course and had a net sectional area 81 square inches while that for Test No. 66 was made of 2-inch solid blocks with 3/8-inch square mesh wire fabric in the joints at corners and was filled solidly within, giving a net area of protective materials of 232 square inches. Although the net area of the covering of No. 4 was only 28 per cent of that of No. 66 its fire endurance limit was 10 per cent in excess of that of the latter. A more direct comparison is that of Test No. 6 with No. 65 of the previous series in which both coverings were of 2-inch solid blocks. The covering of Column No. 6 had band iron cramps at the corners in each course and was unfilled while No. 65 had corrugated wall ties at each corner in

each course and was solidly filled between the blocks and the column shaft. The net sectional area of protective materials for Test No. 6 was 56 per cent of that for Test No. 65 but in spite of this difference its fire endurance limit was 8 per cent greater.

The 2-inch thick monolithic wood-fibered gypsum concrete covering for Column No. 1, notwithstanding the loss of a large portion of the 1/2-inch plaster finish early in the test and the opening of surface cracks, developed a fire endurance limit of 6 hours, 54 minutes.

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